

APPENDIX D—DESTRUCTIVE ANALYSIS OF JT9D DIFFUSER CASES AFTER EXTENDED SERVICE

D.1 JT9D DIFFUSER SECTIONING PLAN.

Each new JT9D diffuser case is a weld assembly of 17 details. These include:

1. Outer center ring (AMS 5663 forged ring)
2. Outer front skirt with integral front flange (AMS 5663 forged ring)
3. Outer rear skirt with integral rear flange (AMS 5663 forged ring)
4. Sheet metal struts; 10 total (AMS 5596 sheet)
5. Inner front ring with integral front flange (AMS 5663 forged ring)
6. Inner rear ring; rolled sheet with axial weld (AMS 5596 sheet)
7. Inner rear flange (AMS 5663 forging)
8. Inner front flange heat shield and support bracket (AMS 5596 sheet)

Final assembly contains five full-circumferential welds, one axial weld, one set of resistance welds (to attach the support bracket to the heat shield) and twenty manually produced fillet welds that connect each of the ten struts to the inner and outer ring assemblies. Figure D-1 is a photograph of a typical JT9D diffuser case. Once in the field, all but the outer center ring are replaceable either in part or as full details. Thus, each of the outer skirts, inner rings, or struts may be replaced rather than repaired. In addition, any of the four flanges, including the three integral flanges, can be separately replaced at the discretion of the operator. Of course local repairs are always an option. Depending on the size and difficulty of the repair weld, the case may be solution heat-treated prior to welding or welded in the as fully heat-treated condition and then short aged.

During normal engine operation, the greater stresses tend to be on the outer pressure wall rings. The higher temperatures meanwhile tend to be concentrated on the inner ring details. Criteria used in sectioning the cases were to try to include samples from all major case details, each of the assembly welds, and examples of repair welds. Several metallographic samples were made of each detail so at each detail, flanges and walls could be examined and sections along the axial length of the case could be examined to determine if there were microstructural differences from front to rear of the case.

As stated in the main body of the report, three of the available seven cases were selected for metallographic (and mechanical property) evaluation. On average, 40 metallographic samples were made out of each case. Sections of one case, (BW0976) were chemically etched prior to excising metallographic samples so local repairs could be more easily located. The etch however attacked the case surfaces irregularly, which made assessment of surface structure impossible, so the acid etching procedure was eliminated.

The following is a brief discussion of the general microstructure and unique features observed among the three cases followed by an atlas of photomicrographs that illustrate the major features. These represent a small portion of the evaluation and only a sample of the documented microstructures.

D.1.1 CASE AG9961 (JA Operated, 53,487 hrs, 23,869 cycles).

All three AMS 5663 details that comprise the outer pressure wall displayed significant banding. The general microstructure was of moderately coarse grains (ASTM 5 and 6) with areas where there was minimal needle delta structure interspersed with bands of high needle delta phase concentrations. Some areas displayed necklace structure, with coarse grains encircled with fine dynamically recrystallized grains. High magnification examination revealed that most grain boundaries were decorated with globular particles, both delta and carbides. Most surfaces displayed a denuded surface layer beneath which was another layer of concentrated needle delta. The denuded layer varied in depth from 0.0006" to 0.0009", while the layer of concentrated needle delta varied in depth from 0.005" to 0.0075".

Inner pressure wall AMS 5663 details had a similar banded delta structure, surface denuded layer, and concentrated delta layer. Here the denuded layer depth varied from 0.0004" to 0.0005", and the delta layer varied in depth from 0.0044" to 0.006". The rear ring, which is a rolled sheet of AMS 5596, displayed a finer grain structure (ASTM 8) with lighter banding but an overall high concentration of needle delta throughout the microstructure. The separate attached rear flange was coarse (ASTM 3-4) with less overall needle delta but with concentrations of delta in blotches rather than more continuous bands.

Struts and heat shield details also displayed a fine grain (ASTM 8-10) structure with scattered needle delta and lighter delta bands.

No defects were detected at any of the assembly welds but numerous small defects were detected at most of the repair welds. These consisted of gas pores, near HAZ cracks and cracks in "far" HAZ regions. Many, but not all of the repair welds also displayed heavy concentrations of needle delta adjacent to the welds. Cracking at the tip of the resistance weld that attaches the heat shield to its support bracket was discovered. One large crack was found that extended for more than three-quarters of the thickness of a strut attachment weld. It must be noted that when case S/N AG9961 was scrapped, it contained a number of defects that were left without repair, so it should not be implied that the large weld crack at the strut would not have been detected.

Representative photographs of the metallurgical conditions are shown in figures D-2 through D-6.

D.1.2 CASE BW0976 (BA Operated, 63,092 hrs., 13,696 cycles).

The forward skirt and front flange of the outer pressure wall displayed a varied amount of needle delta phase. Grain size varied from moderate (ASTM 6) to coarse (ASTM 4), banding was not prominent, but the heavy concentrations of delta along the grain boundaries extended out to create areas of near solid blocks of high needle concentrations. The outer center ring displayed more delta than did the forward skirt, and the rear skirt in turn displayed even heavier concentrations of needle delta than did the center ring. Almost all areas of the outer rear skirt, including the rear flange, displayed a microstructure marked by very high concentrations of needle delta phase. Surface denuded layers varied in depth from 0.0003" to 0.0009", and layers of concentrated delta extended inward from the surface with depths between 0.0030" and

0.0150". The deepest denuded layers and delta plate layers were on the forward skirt. Concentrations of delta needles were also found associated with the threads on the tapped boltholes located on the inner surface of the forward skirt.

The inner cylinder of case BW0976 presented a myriad of microstructures. The forward flange was a very fine grain (ASTM 10-11) forging that obviously was a replacement for the original integral flange. Microstructure for this piece consisted of globular delta in the grain boundaries and no needle-shaped delta phase. The forward ring was moderately coarse-grained (ASTM 4-6) consisting of generally equiaxed grains with heavy grain boundary needle delta precipitation. Patches of very heavy delta concentrations were observed throughout the material. The rear cylinder (AMS 5596 sheet) was fine grain (ASTM 8-9) with extensive amounts of delta plates scattered somewhat evenly among the microstructure. The separate rear flange was another fine grain (ASTM 11-12) forging with scattered globular delta and no needle delta phase. The heat shield was moderately coarse grain (ASTM 5) while the supporting bracket was much finer (ASTM 6). Both the heat shield and bracket had extensive needle delta phase distributed evenly throughout the microstructure. Surface denuded layers as deep as 0.0009" and surface layers of concentrated needle delta were detected as deep as 0.013". The heat shield also had a shallow oxide layer (0.00015") with oxide spikes or cracks extending into the denuded surface layer. Neither of the very fine-grained flanges displayed any evidence of concentrated needle delta on their respective surfaces but did display a denuded surface layer.

Grain size of the sheet material used to construct the struts was moderate fine grain (ASTM 6-7) but like the other sheet metal details displayed extensive amounts of needle delta phase scattered evenly throughout the microstructure.

Assembly and repair welds on the outer pressure wall were generally sound but several contained large pools of laves phase. Often the adjacent base metal also contained very high concentrations of needle delta phase. Numerous cracks were observed emanating outward from the bracket to heat shield resistance weld and within the fusion zone of the heat shield/bracket assembly weld.

Representative photographs of the metallurgical conditions are shown in figures D-7 through D-12.

D.1.3 CASE CJ3225 (JA Operated, 60,307 hrs., 19,260 cycles).

Within the outer pressure wall, heavy concentrations of needle-shaped delta phase were present throughout the forward skirt (and flange) and in patches and at grain boundaries of the center ring and rear skirt details. The rear skirt displayed the least of the patches but in the thicker sections of the skirt concentrations of needle delta could be extensive. The amount of evenly distributed delta phase in the forward and center rings made it difficult to ascertain if a surface layer of high delta phase concentration existed. However, a surface denuded layer of 0.00078" was observed on the forward skirt regions of the case. Heavy concentrations of delta needles were also observed associated with the tapped lugs on the forward skirt.

The forward ring (and flange) of the inner pressure wall consisted of a duplex microstructure, typically ASTM 4-5, in grain size, but many of the coarse grains were surrounded by a necklace structure of finer grains. The rear ring was finer grain sheet (ASTM 6-7) with heavy delta concentrations of delta phase throughout, while the rear flange was marked by delta phase concentrations in patches.

The sheet metal struts were relatively fine grained with extensive needle delta phase scattered throughout.

This case displayed many repair welds on the outer and inner pressure wall. Many of the welds also displayed subsurface cracks within the weld fusion zone. The numerous layers of weld bead observed suggest that many of the welds are repairs over previous welds. However, there is no way to prove this conclusively. Cracks, lack of fusion, and gas pores were all observed within the fusion zone material of the case. However, in many cases, these regions were actually HAZs to subsequent repairs.

Representative photographs of the metallurgical conditions are shown in figures D-13 through D-17.

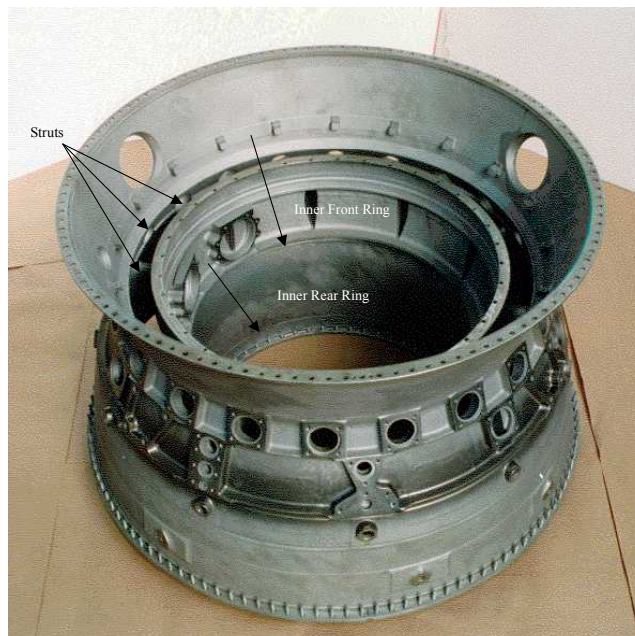
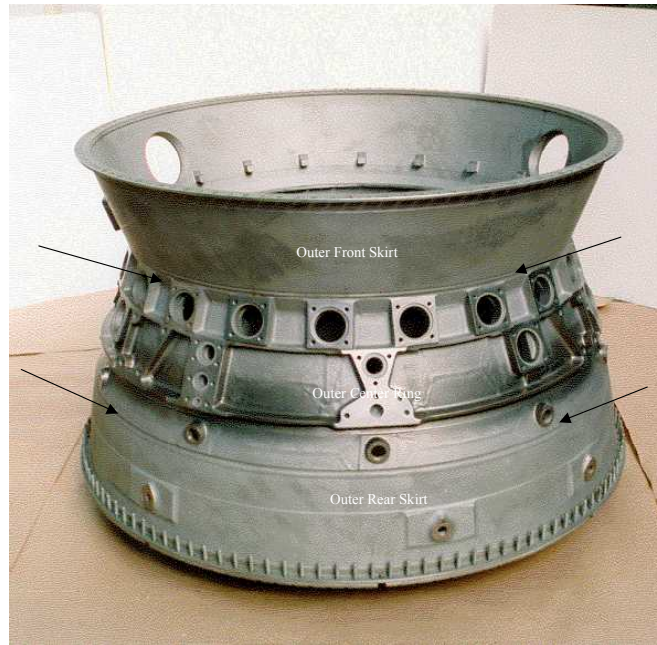


FIGURE D-1. VIEWS OF A JT9D DIFFUSER CASE FROM A SIDE PROFILE POSITION (UPPER) AND FROM A FORWARD POSITION LOOKING AFT (The major details are labeled and the arrows indicate where major circumferential assembly welds are placed.)



Outer Front Flange 400X



Outer Front Skirt 400X



Outer Center Ring 100X



Outer Center Ring 400X

FIGURE D-2. JT9D DIFFUSER S/N AG9961, GENERAL MICROSTRUCTURES OF OUTER PRESSURE WALL DETAILS



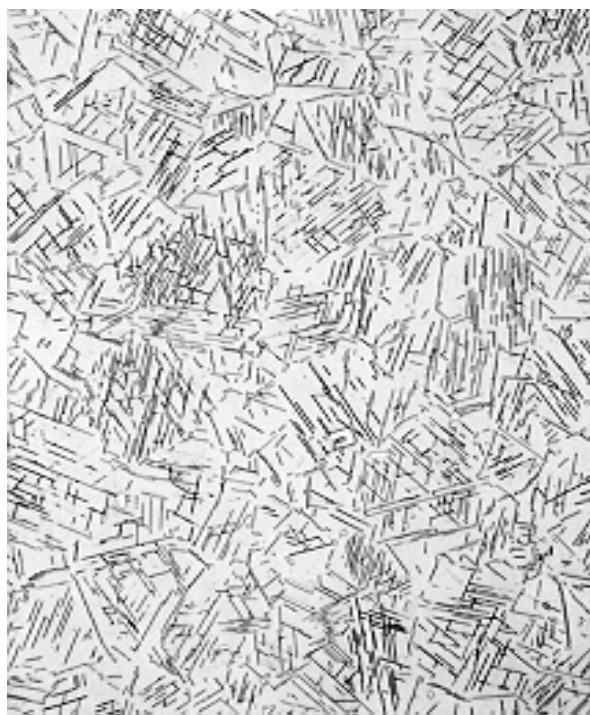
Outer Rear Skirt

400X



Outer Rear Flange

400X



Inner Rear Ring

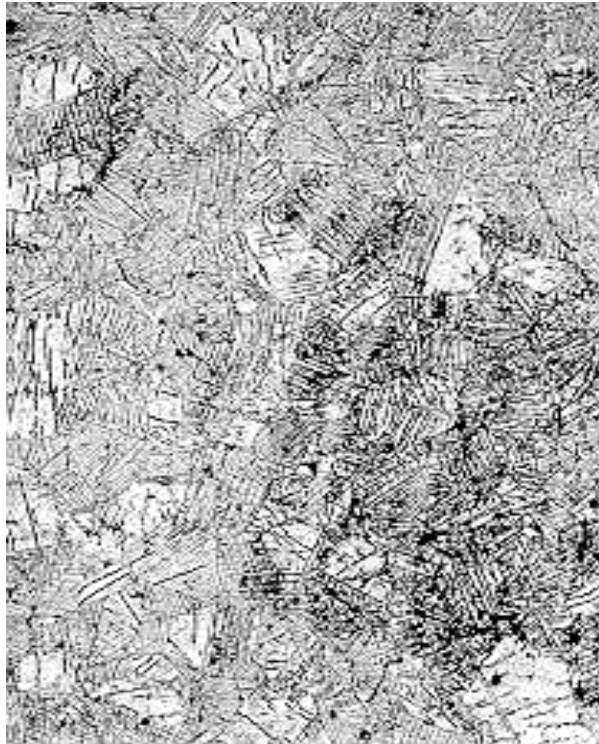
400X



Inner Rear Flange

400X

FIGURE D-3. JT9D DIFFUSER S/N AG9961, GENERAL MICROSTRUCTURES OF OUTER REAR (UPPER) AND INNER REAR (LOWER) RING DETAILS



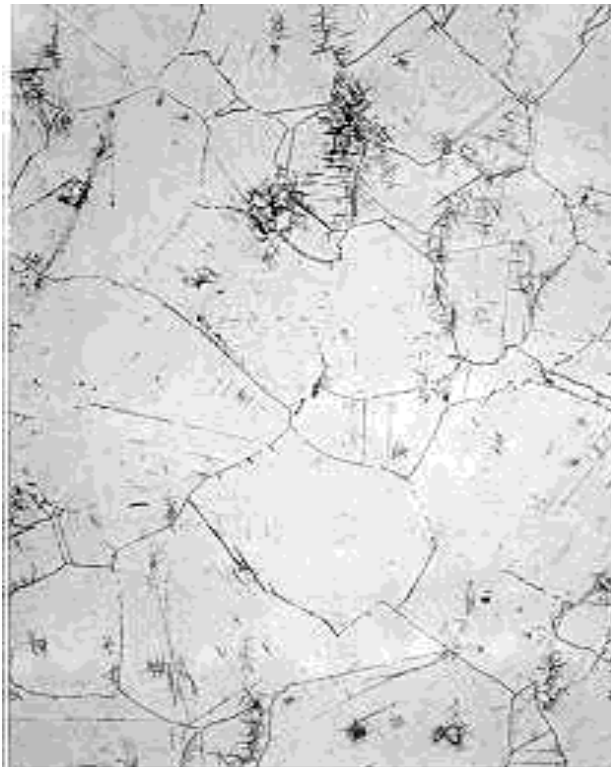
Inner Front Flange

100X



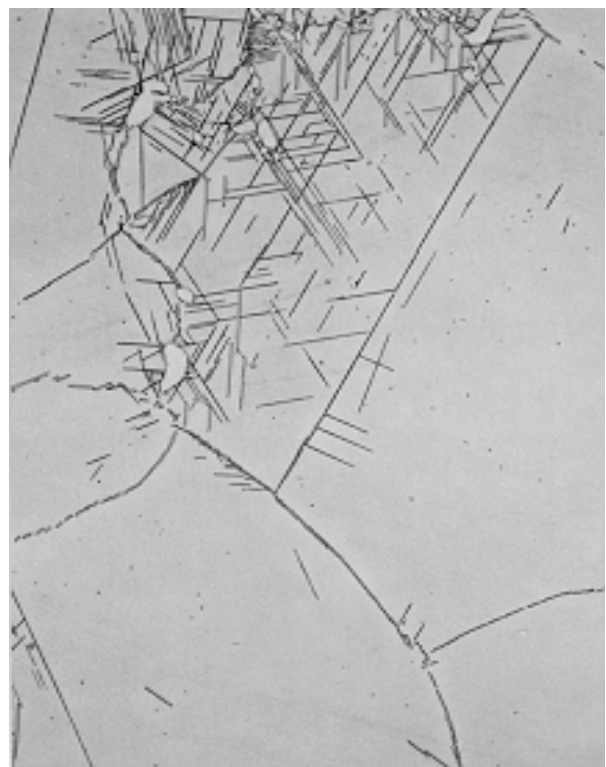
Inner Front Flange

400X



Inner Front Ring

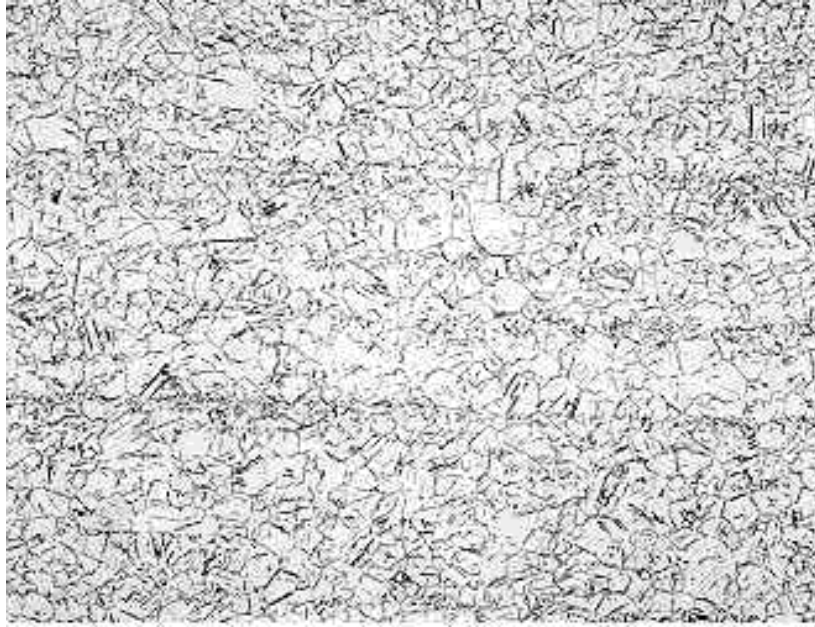
100X



Inner Front Ring

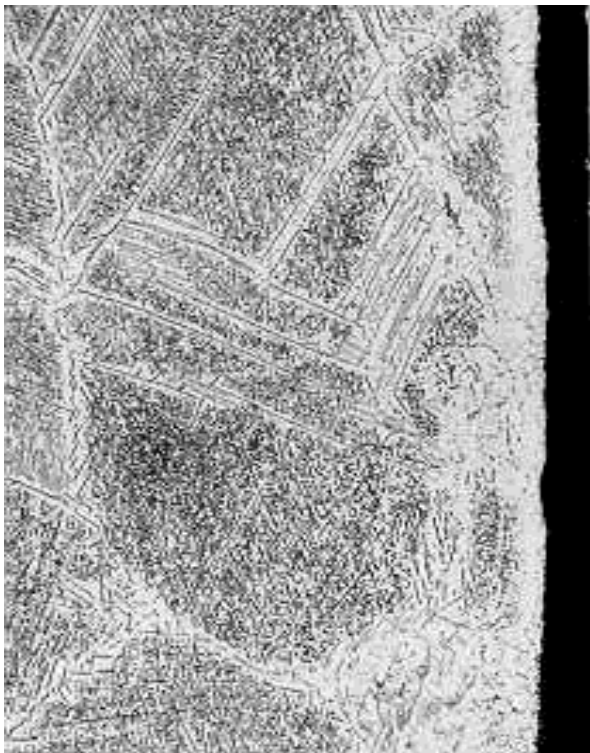
400X

FIGURE D-4. JT9D DIFFUSER S/N AG9961, GENERAL MICROSTRUCTURES OF THE INNER FRONT RING DETAIL



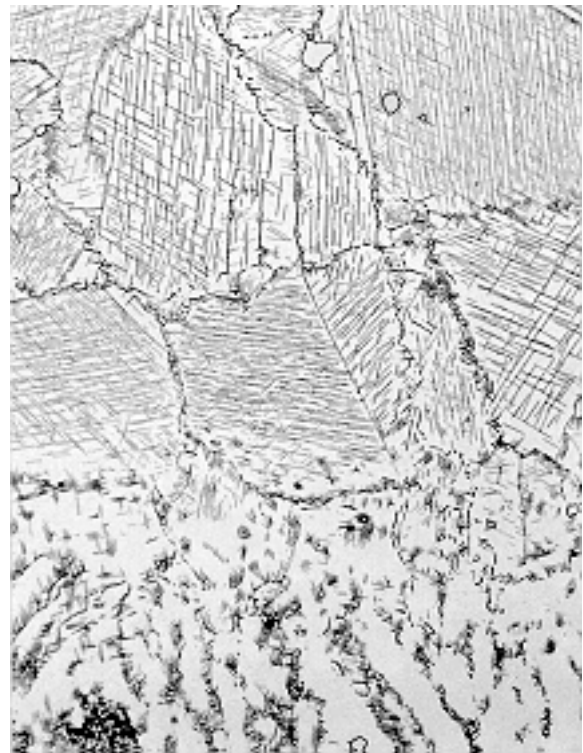
Strut Sidewall

200X



Surface Delta Concentration

400X



Weld HAZ Delta Concentration

400X

FIGURE D-5. JT9D DIFFUSER S/N AG9961, GENERAL MICROSTRUCTURES OF THE STRUT (UPPER) SHEET MATERIAL AND HEAVY CONCENTRATIONS OF NEEDLE DELTA PHASE ASSOCIATED WITH SOME SURFACES (LOWER LEFT) AND WELD HAZ (LOWER RIGHT)



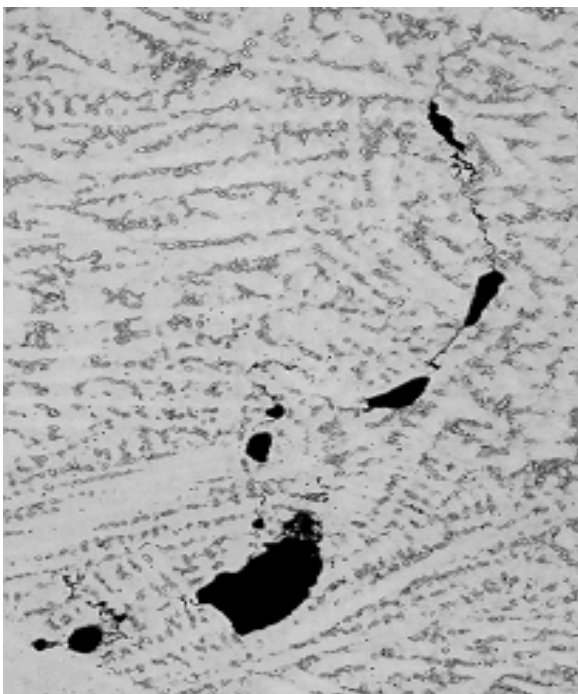
Strut Attachment Weld

20X



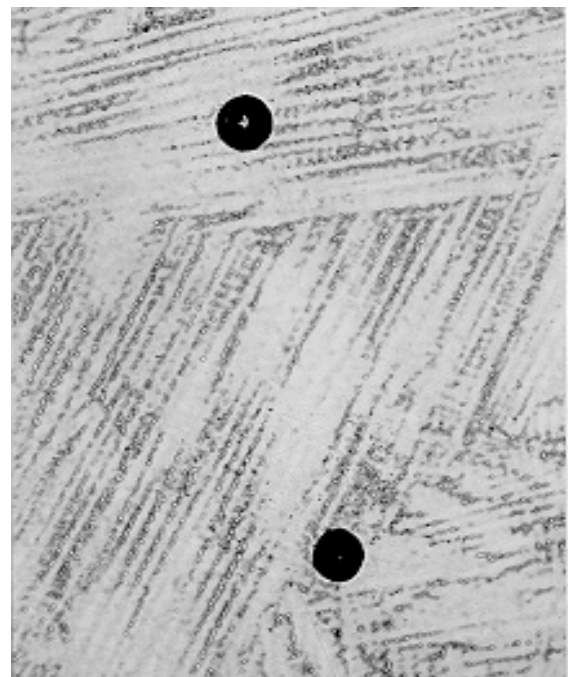
Repair Weld

25X



Repair Weld

200X



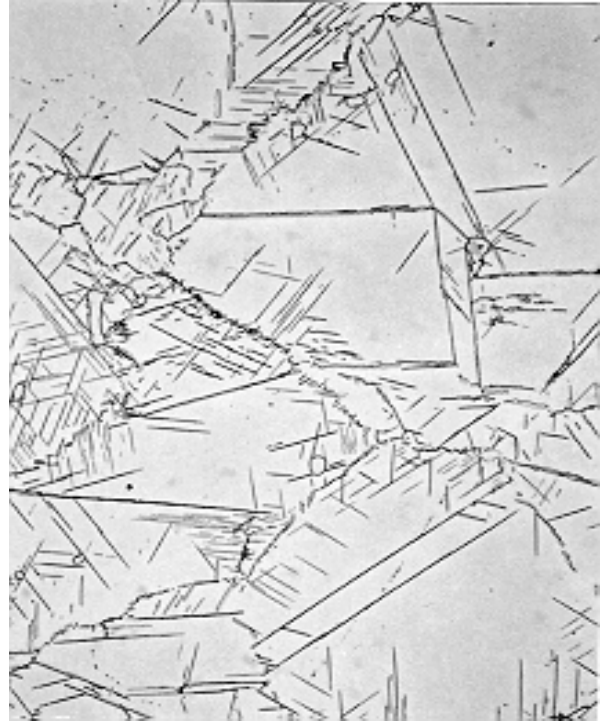
Repair Weld

200X

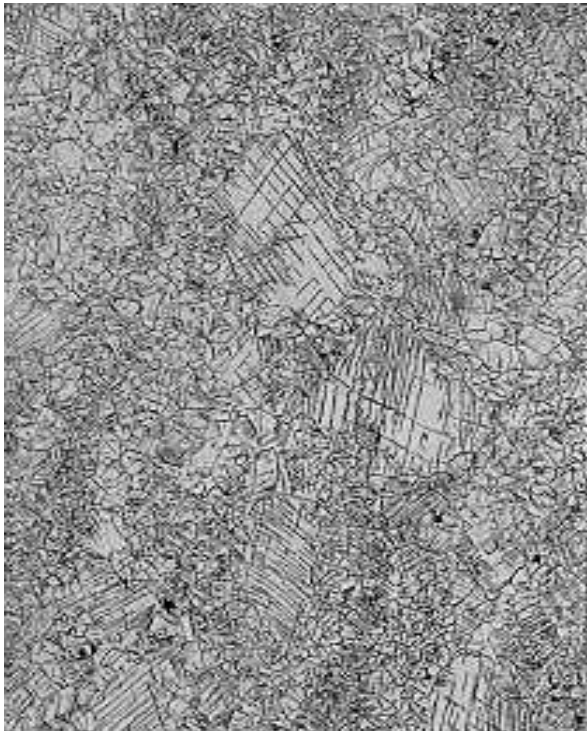
FIGURE D-6. JT9D DIFFUSER S/N AG9961, TYPICAL WELD DEFECTS INCLUDING CRACKS (UPPER), LACK OF FUSION (LOWER LEFT), AND GAS PORES (LOWER RIGHT)



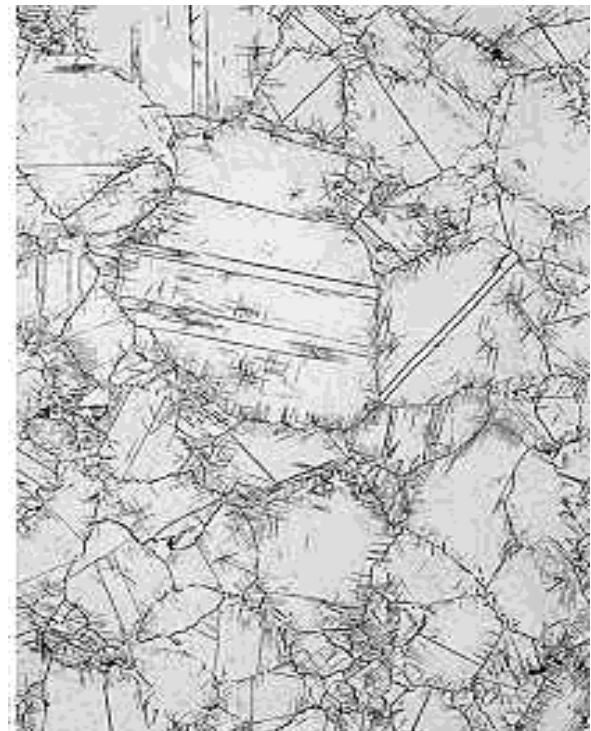
Outer Forward Flange 100X



Outer Forward Flange 400X



Outer Forward Skirt 100X



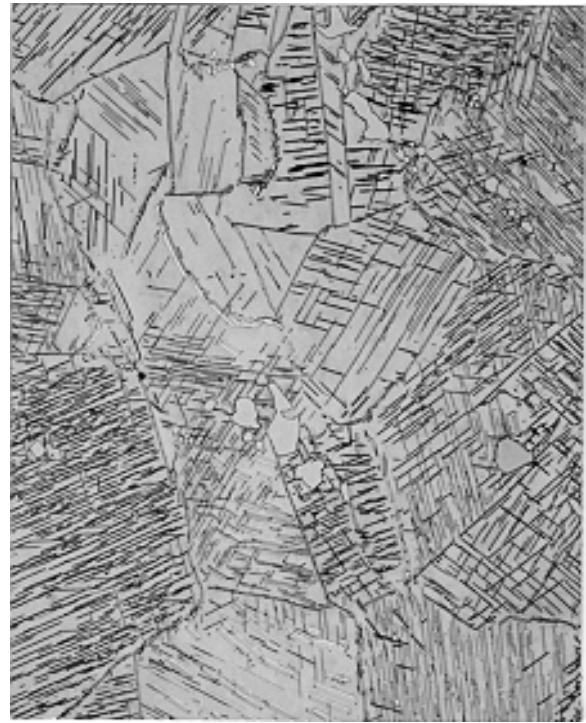
Outer Forward Skirt 100X

FIGURE D-7. JT9D DIFFUSER S/N BW0976, GENERAL MICROSTRUCTURES OF THE OUTER FRONT SKIRT DETAIL



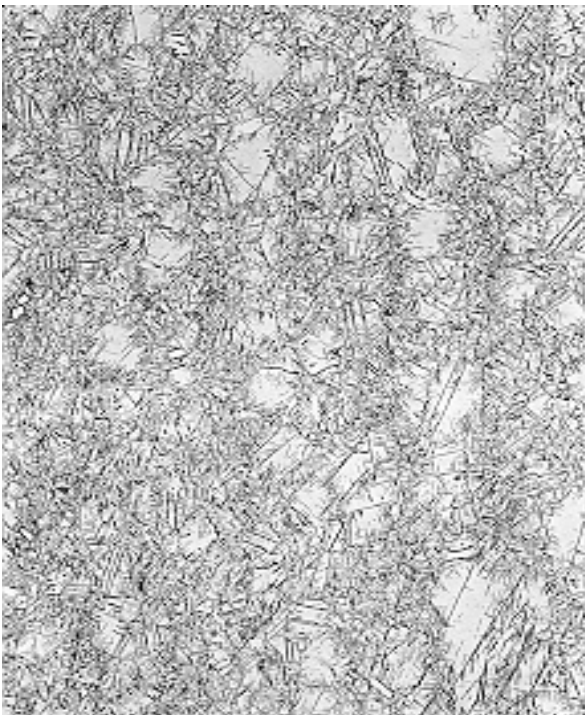
Outer Front Skirt

400X



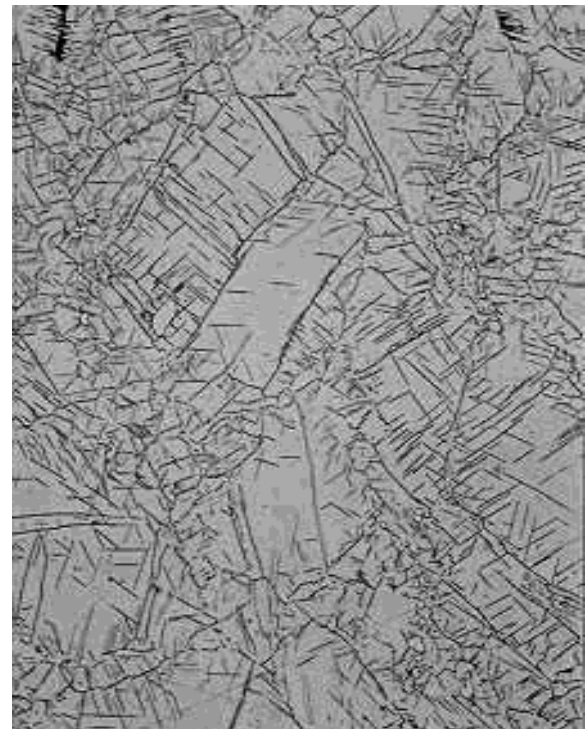
Outer Rear Skirt

400X



Outer Center Ring

100X



Outer Center Ring

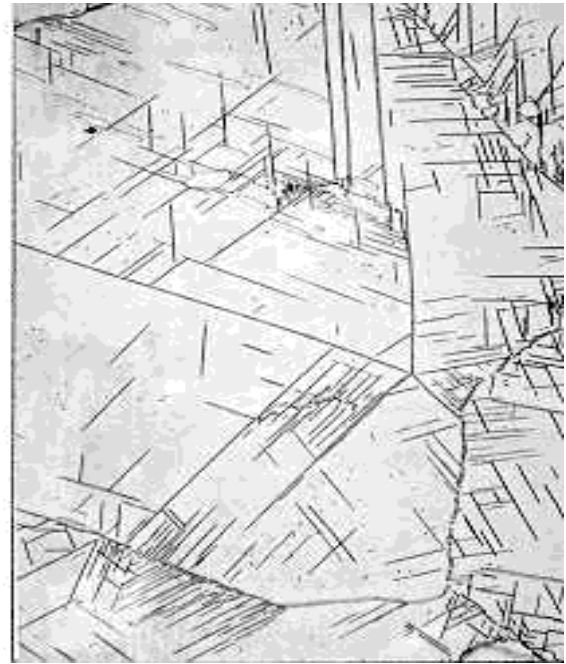
400X

FIGURE D-8. JT9D DIFFUSER S/N BW0976, GENERAL MICROSTRUCTURES OF THE OUTER FRONT SKIRT (UPPER LEFT), OUTER REAR SKIRT (UPPER RIGHT), AND OUTER CENTER RING DETAILS



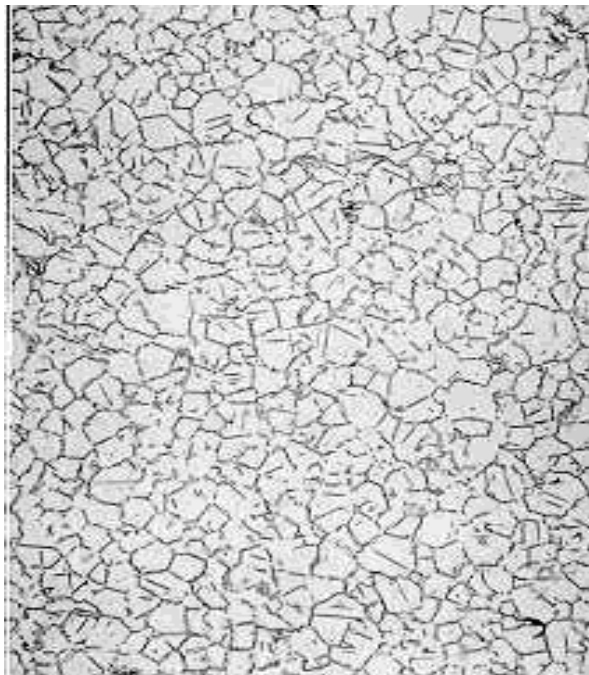
Inner Front Ring

100X



Inner Front Ring

400X



Inner Front Flange

400X

FIGURE D-9. JT9D DIFFUSER S/N BW0976, GENERAL MICROSTRUCTURES OF THE INNER FRONT RING DETAIL (The much finer grain microstructure of the flange (lower) relative to the detail ring wall (upper) illustrates that this front flange is a repair replacement flange attached sometime in the service life of the case.)



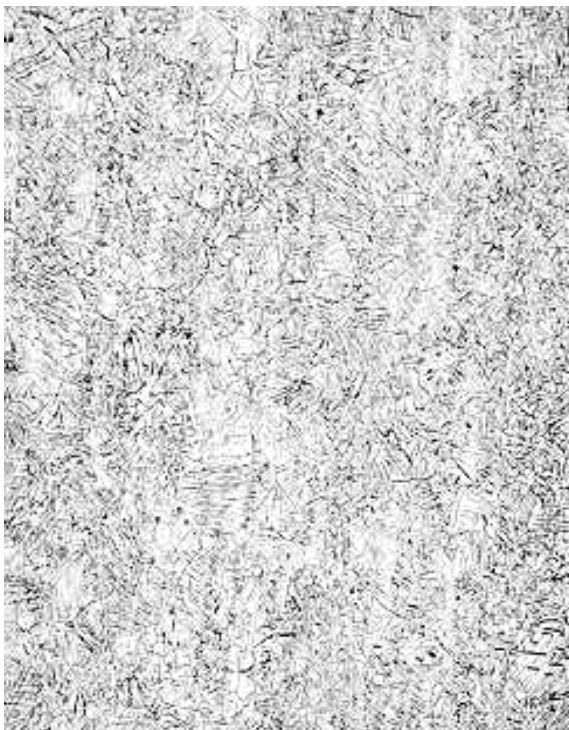
Inner Rear Ring

400X



Inner Rear Flange

400X



Strut Sidewall

100X



Strut Sidewall

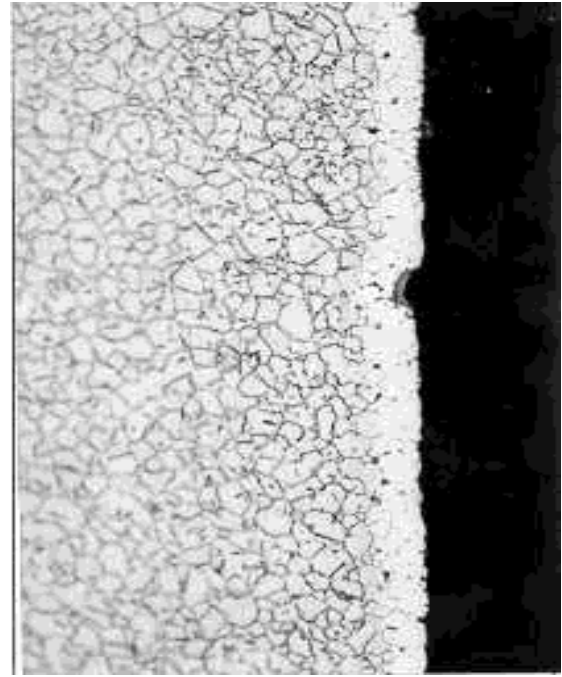
200X

FIGURE D-10. JT9D DIFFUSER S/N BW0976, GENERAL MICROSTRUCTURES OF THE INNER REAR RING (UPPER) AND STRUT (LOWER) DETAILS



Heat Shield

400X



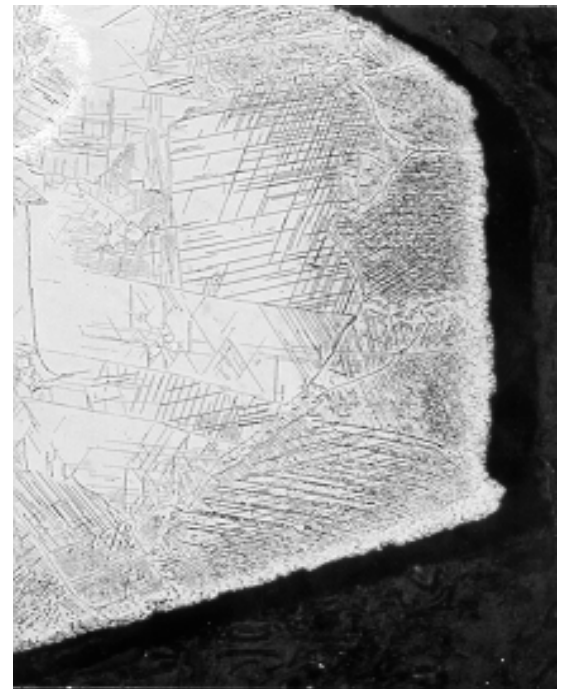
Inner Front Flange

400X



Outer Front Flange

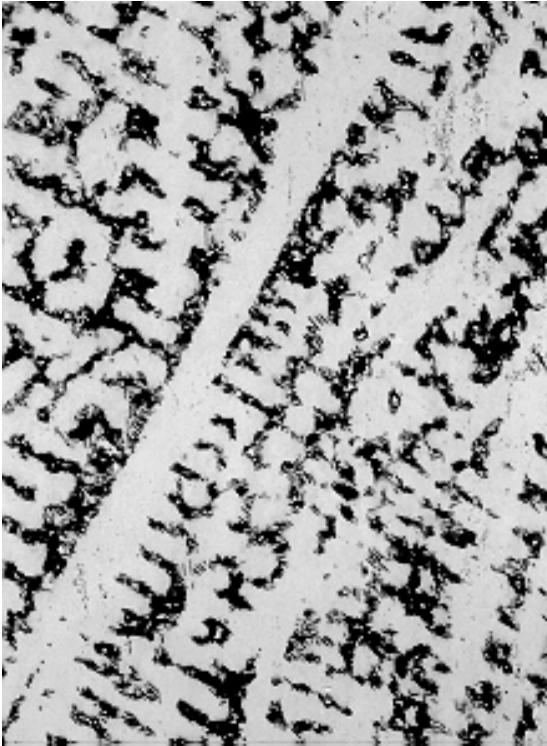
200X



Tapped Hole Thread

200X

FIGURE D-11. JT9D DIFFUSER S/N BW0976, EXAMPLES OF SURFACE DEPLETION ON INNER CASE DETAILS (UPPER) AND CONCENTRATED NEEDLE DELTA ASSOCIATED WITH SOME SURFACES (LOWER LEFT) AND THREADS (LOWER RIGHT)



Outer Front Skirt 400X



Outer Center Ring 400X

FIGURE D-12. JT9D DIFFUSER S/N BW0976, REPAIR WELD MICROSTRUCTURES
(The higher (slightly) concentration of needle delta in the weld located on the center ring (right) relative to the front skirt repair (left) suggests that the center ring repair was exposed to more re-solution heat treatments over the service life of the case.)



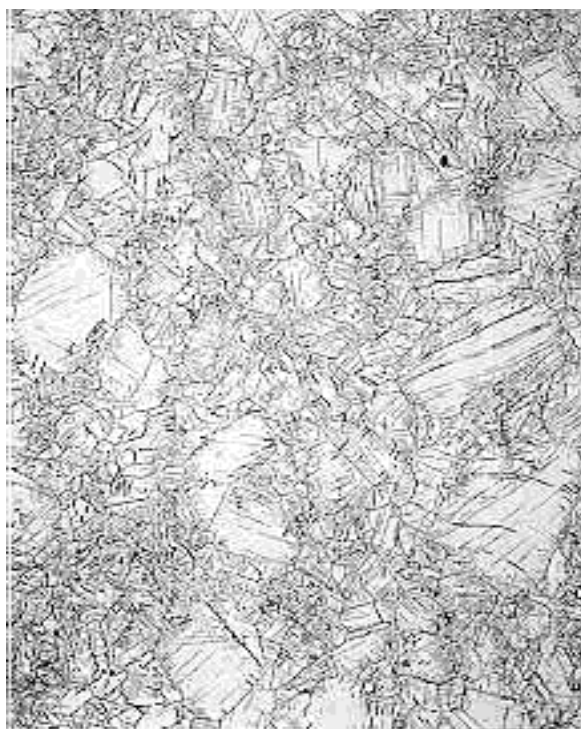
Outer Front Flange

400X



Outer Front Skirt

400X



Outer Center Ring

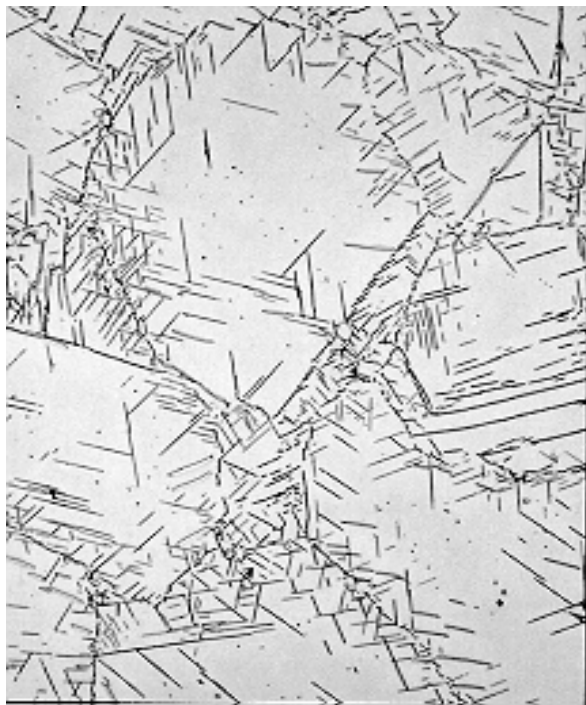
100X



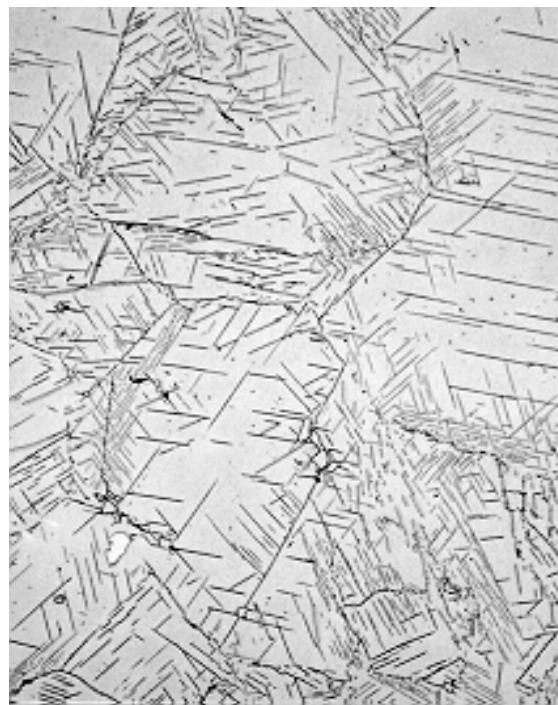
Outer Center Ring

400X

FIGURE D-13. JT9D DIFFUSER S/N CJ3225, GENERAL MICROSTRUCTURES OF THE OUTER FRONT SKIRT (UPPER) AND OUTER CENTER RING (LOWER) DETAILS



Outer Rear Skirt 400X



Outer Rear Flange 400X



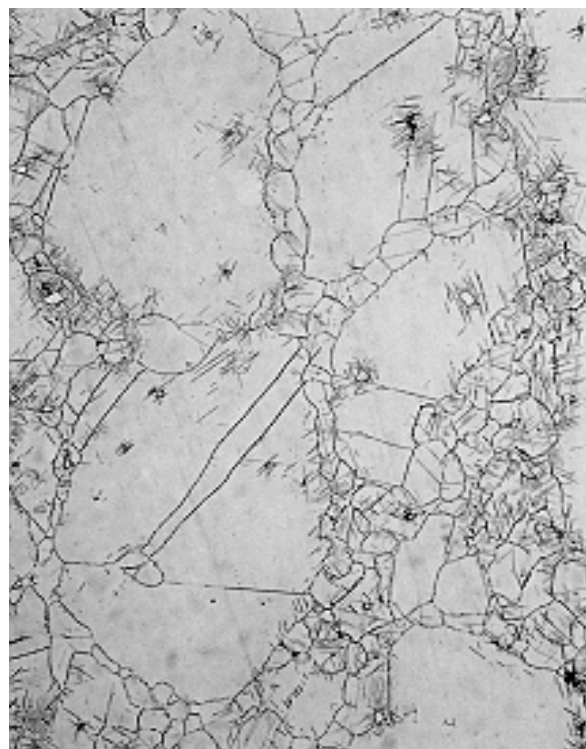
Strut Sidewall 200X

FIGURE D-14. JT9D DIFFUSER S/N CJ3225, GENERAL MICROSTRUCTURES OF THE INNER REAR RING (UPPER) AND STRUT (LOWER) DETAILS



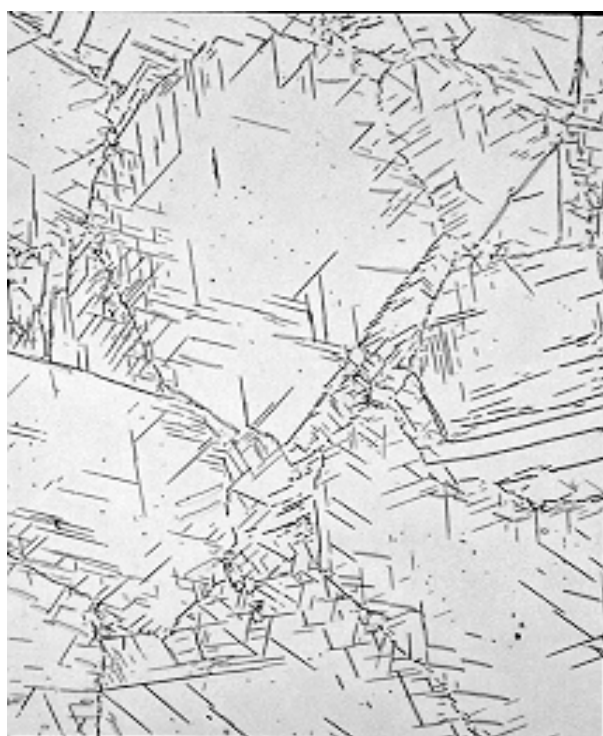
Inner Front Ring

100X



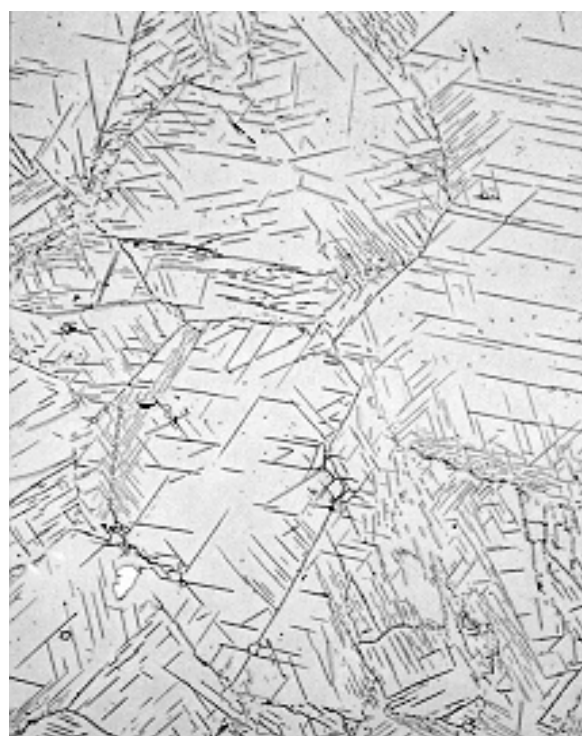
Inner Front Ring

100X



Inner Front Ring

400X



Inner Front Flange

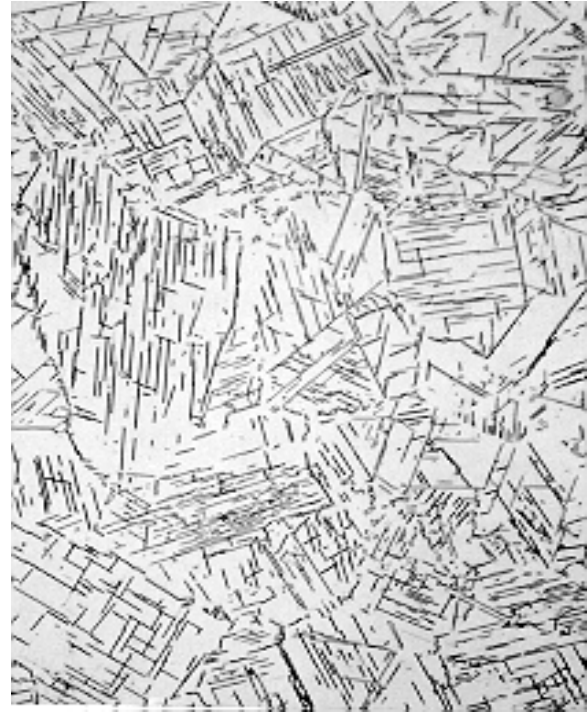
400X

FIGURE D-15. JT9D DIFFUSER S/N CJ3225, GENERAL MICROSTRUCTURES OF THE INNER FRONT RING DETAIL



Inner Rear Ring

200X



Inner Rear Ring

400X



Inner Rear Flange

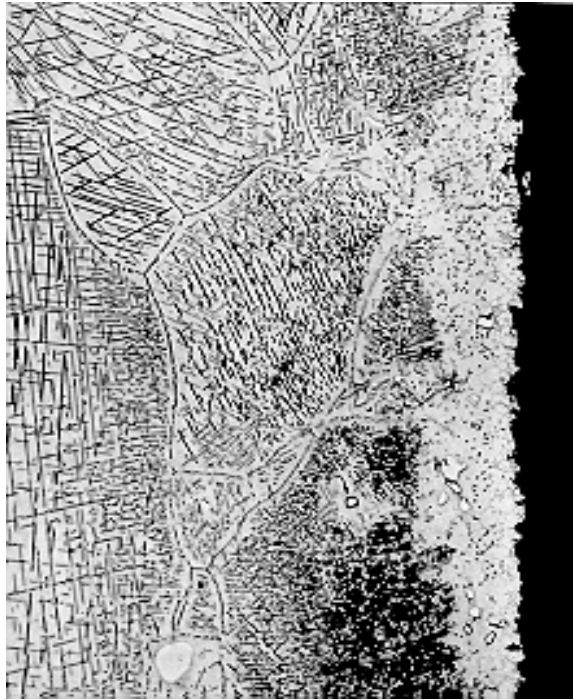
200X



Inner Rear Flange

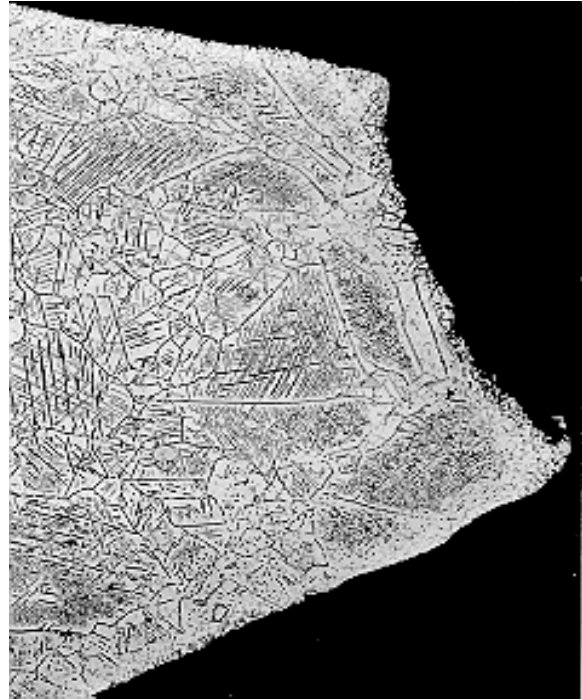
400X

FIGURE D-16. JT9D DIFFUSER S/N CJ3225, GENERAL MICROSTRUCTURES OF THE INNER REAR RING DETAILS



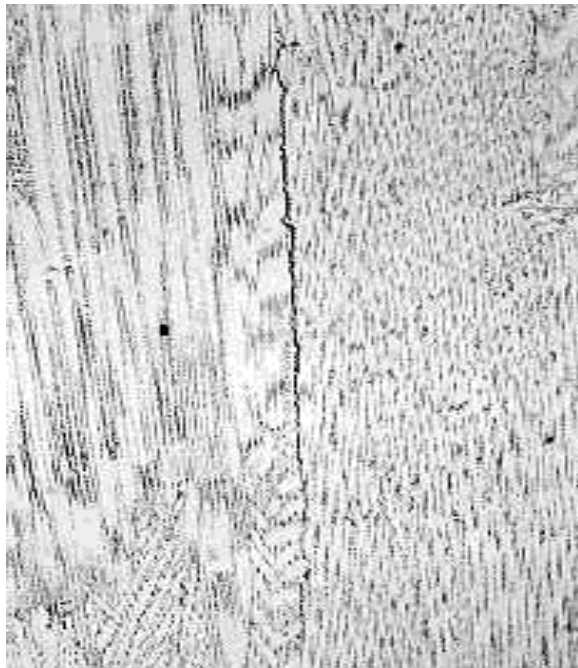
Inner Forward Ring

400X



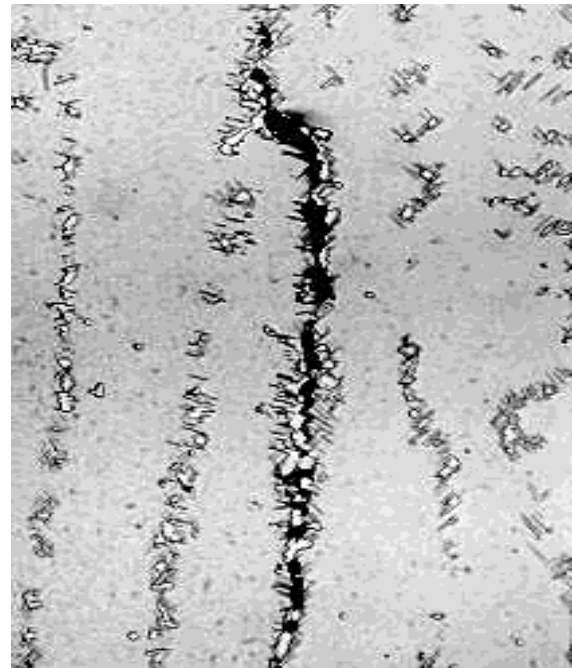
Outer Pressure Wall Tapped Hole

200X



Outer Center Ring Repair

50X



Outer Center Ring Repair

1000X

FIGURE D-17. JT9D DIFFUSER S/N CJ3225, HEAVY CONCENTRATIONS OF NEEDLE DELTA ASSOCIATED WITH SOME SURFACES (UPPER LEFT) AND TAPPED HOLE THREADS (UPPER RIGHT) AND REPAIR WELD CRACKS (LOWER)
(The crack illustrated in the lower right figure is associated with interdendritic concentrations of laves phase.)